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DEVELOPMENT OF A POLYCOMPONENT FAT EMULSION AND STUDY OF ITS PHYSICOCHEMICAL PROPERTIES

Summary: *This article focuses on the development of a polycomponent fat emulsion and the investigation of its physicochemical properties. The emulsion exhibited a moderately acidic pH of 5.64 ± 0.12, indicating suitability for food applications and consistent structural stability. The structured lipid matrix, formed by rice bran wax and stabilized with chickpea flour, maintained emulsion integrity during storage at 4 °C. Water activity (aw) was measured at 0.947, reflecting a relatively high level of free moisture typical of oil-in-water food emulsions, emphasizing the need for proper storage conditions to ensure microbiological stability. Rheological analysis revealed shear-thinning behavior, with apparent viscosity decreasing from 83.43 to 29.60 mPa·s as rotational speed increased, demonstrating progressive disruption of internal interactions under stress. Color and oil binding capacity measurements confirmed a visually uniform and stable system. Overall, the emulsion combines improved lipid composition with desirable technological properties and has potential as a structured fat system or partial animal fat replacer in various food products. Further studies will investigate the possibility of using this emulsion as a partial animal fat replacer in cooked sausage products.*

Key words: *polycomponent emulsion; safflower oil; horse fat; rice bran wax; chickpea flour; polyunsaturated fatty acids; fat replacer.*

1 Introduction

Meat and dairy products are widely consumed worldwide due to their palatability, convenience, and affordability. However, these food categories are typically characterized by a high content of saturated fatty acids, excessive intake of which has been associated with an increased risk of cardiovascular diseases, obesity, hypercholesterolemia, and hypertension [1, 2].

A promising strategy to mitigate these health concerns involves the partial or complete replacement of saturated fats with plant-based oils and lipids. Similar to conventional animal fats, vegetables oils contribute significantly to the sensory attributes of food products by influencing color, flavor development during thermal processing, and overall taste. They also enhance mouthfeel and promote satiety [3].

Compared with protein or carbohydrate based fat substitutes, which often fail to fully replicate the functional and sensory properties of fats, plant oils represent a more technologically suitable and organoleptically acceptable alternative [4].

Moreover, plant oils possess a more favorable fatty acid profile, being rich in unsaturated fatty acids, including monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). These fatty acids have been linked to reduced low-density lipoprotein cholesterol levels and decreased inflammatory responses associated with cardiovascular diseases [5].

Animal fats play a crucial technological, sensory, and nutritional role in food products. They contribute significantly to texture, flavor intensity, and juiciness, thereby enhancing overall product quality [6].

However, saturated fats are energy-dense components and are recognized as a major contributor to elevated plasma cholesterol levels, which are associated with an increased risk of cardiovascular diseases. These conditions pose a significant health threat, particularly for individuals with coronary artery disorders [7].

Amid growing concerns regarding environmental sustainability, animal welfare, and the potential for allergic reactions, the incorporation of alternative plant-based ingredients into food formulations has gained increasing attention and popularity [8].

2 Materials and methods

The study materials included safflower oil and horse abdominal fat as sources rich in polyunsaturated fatty acids, while rice bran wax was used as a structuring agent, and chickpea flour and water served as stabilizing components. Rice bran wax (RBW) was supplied by a certified food-grade manufacturer, while the remaining ingredients were purchased from a local market. The experiments were conducted in the research laboratory of S.Seifullin Kazakh Agrotechnical Research University. The prepared samples were stored at 4 °C for 24 hours prior to analysis.

The oil content in safflower seeds ranged from 23.08% to 36.51%. Linoleic acid was identified as the predominant fatty acid in safflower oil, accounting for 55.1-77.0% of the total fatty acid composition, with an average value of 70.66% [9].

Horse fat also contains significant polyunsaturated fatty acids (PUFAs), particularly linoleic acid (18:2n-6) and alpha-linolenic acid (18:3n-3), the levels of which may vary depending on the animal's diet and breed [10].

Chickpea flour was incorporated as a natural emulsifier due to its content of proteins and phospholipids. These components absorb at the oil-water interface, forming a protective layer around lipid droplets and thereby preventing phase separation of the emulsion. In addition, chickpea flour contributes to structural stabilization and enhances fat-binding capacity, which is particularly important in systems with a high proportion of animal fat [11].

Rice bran wax (RBW), a by-product of rice milling, is a sustainable, low-cost, and natural gelator composed primarily of long-chain saturated fatty alcohols and esters. Several studies have shown the successful use of rice wax to structure oils such as soy, sunflower, and corn, improving their oxidative stability, mechanical strength, and suitability for use in baked goods, spreads, and meat substitutes [12].

2.1 Emulsion Preparation

The emulsions were prepared using safflower oil and horse abdominal fat structured with rice bran wax (RBW), chickpea flour, and water. The optimal formulation was determined using a mathematical model developed in Minitab 19 software. The visual appearance and structural differences of the emulsions are presented in Figure 1.

Figure 1 – The visual appearance and structural differences of the emulsions

First, horse abdominal fat was melted in a thermostat at 60°C for 30 minutes. Subsequently, rice bran wax, previously melted in a water bath at 75°C for 10 minutes, was blended with safflower oil and added to the melted fat phase. Chickpea flour was dispersed in water and allowed to hydrate for 15 minutes. All components were then combined and homogenized for 15 minutes. The resulting mixture was cooled at room temperature for 30 minutes, followed by storage at 4 °C for 24 hours to allow gel formation. The emulsions were stored in airtight containers to prevent oxidation prior to analysis. All analytical measurements were performed in triplicate for each batch, and the results are presented as mean values ± standard deviation. The visual appearance and structural differences of the emulsions presented in Figure 2.

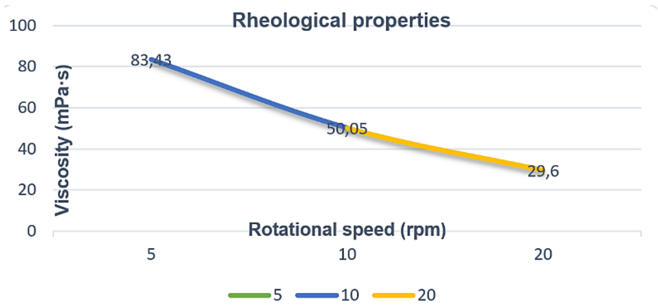

Figure 2 – The rheological indicators of the emulsion

2.2 Texture analysis

The texture profile attributes of the emulsions, firmness and spreadability, were analyzed by a Texture AnalyzerTX-700 (France). Such parameters are crucial to mimic the sensory and mechanical responses of the gels during their manipulation and food processing. For all tests, emulsion samples were prepared using cylindrical molds and equilibrated at room temperature (25°C) for a minimum of 1 h before testing [13]. A cylindrical stainless steel (5 mm diameter) probe was inserted into the gel surface at 1 mm/s to a set depth of 10 mm. The penetrating force was reported as firmness (N), and the spreadability was estimated from the area under the curve or lower resistance during penetration. All results were obtained in triplicate, and values represent mean ± SD. This approach is a model of application in which emulsions are spread or cut and mimics normal texture profile analysis setup used in lipid structuring research.

2.3 Determination of pH acidity

The acidity (pH) of meat was determined by the potentiometer method. To obtain information, the pH tester METTLER TOLEDO (Switzerland) portable conductometer S3 Standard Kit was used. Before analysis, the pH tester is calibrated using a special standard solution mixed with distilled water with PH 4.0 and 7.0. This was done simply by immersing two electrodes in the solution and taking a pointer. The sample was made 3 times, and then the average indicator of the samples was calculated.

2.4 Emulsion Colour

The colour of the emulsions was assessed using a Chroma Meter CR-400 (Konica Minolta, Inc., Tokyo, Japan). The results were express in accordance with the CIELAB system with reference to illuminate D65 and a visual angle of 10◦ . The parameters determined were L* (L* = 0 (black) and L* = 100 (white)), a* (−a* = greenness and +a* = redness), b* (−b* = blueness and +b* = yellowness). The samples were poured into a granular-materials attachment CR-A50 (Konica Minolta, Inc., Tokyo, Japan) and measured in triplicate.

2.5 Oil Binding Capacity (OBC)

Oil binding capacity (OBC) was measured to evaluate the ability of the oleogel network to retain oil under centrifugal force. Approximately 5 g of each oleogel sample was centrifuged at 4000 rpm for 20 min at 25°C. The released oil was decanted and weighed, and OBC was calculated as the percentage of oil retained within the gel matrix. Increased RBW content resulted in a more cohesive crystalline network and higher OBC.

The Oil Binding Capacity was calculated using the formula:

$$\mathrm{OBC} = \frac{\mathrm{Wi} - \mathrm{Wo}}{\mathrm{W1}}$$

Where Wi: initial sample weight, Wo: weight of separated oil.

Analyses were performed in triplicate and the means were calculated. This procedure is a modification of the methods published, ensuring consistency with prior research.

2.6 The water activity (aw)

The water activity (aw) of the developed emulsion was determined using an AQUALAB 4TE water activity analyzer. Prior to analysis, the instrument was calibrated using standard salt solutions according to the manufacturer's instructions. Approximately 2 g of the emulsion sample was placed into a measurement cup and inserted into the instrument chamber.

Measurements were carried out at a constant temperature of 25°C. The instrument sensor measures the equilibrium vapor pressure of water above the sample and automatically calculates the water activity value.

All measurements were performed in triplicate, and the results were expressed as mean value ± standard deviation.

3 Results and Discussion

The rheological properties of the emulsion were evaluated using a structurometer under controlled rotational speeds of 5, 10, and 20 rpm. Apparent viscosity (mPa·s) and torque (%) were recorded for each measurement. All analyses were performed at constant temperature conditions.The rheological indicators of the emulsion presented in Figure 2.

The apparent viscosity of the emulsion decreased from 83.43 to 29.60 mPa·s as the rotational speed increased from 5 to 20 rpm, indicating a shear-thinning behavior. Such rheological characteristics are typical for structured emulsion systems where internal interactions between dispersed droplets weaken under shear stress.

The torque value at 20 rpm (10,5%) was within the recommended measurement range, ensuring the reliability of the obtained data. Lower rotational speeds resulted in borderline torque values, which were considered for trend analysis only. Pang, M. et al. studied the rheological properties of the emulsion developed by the authors as a fat substitute in the manufacture of food products [14, 15].

The studied emulsion exhibited pseudoplastic flow behavior, combining structural stability at rest with improved flowability under processing conditions.

The pH indicators of the emulsion presented in Figure 3.

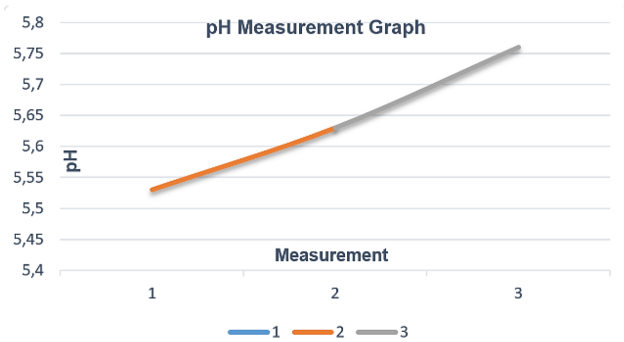

Figure 3 – pH indicators of the emulsion

The pH value of the emulsion was determined in triplicate. The mean pH was 5.64 ± 0.12 at 26.1°C, indicating slight acidity and stability of the emulsion system. Zhang H et al. studied the purpose of this study was to investigate the influence of pH on properties and stability of oil-in-water emulsions using pectin as an emulsifier and zein as an auxiliary emulsifier [16]. The color parameters of the emulsion presented in Figure 4.

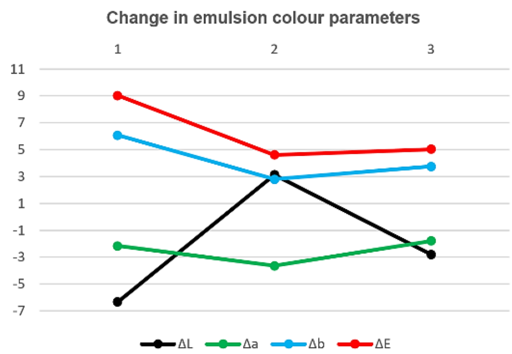

Figure 4 – The color parameters of the emulsion

The color parameters of the emulsion were determined using a colorimetric method. The color characteristics were evaluated in the CIELab color space (L*, a*, b*), and the differences were expressed as ΔL, Δa, Δb and the total color difference ΔE. The sample was measured three times during the study.

According to the obtained results, during the first measurement the following values were recorded: ΔL = -6.33, Δa = -2.17 and Δb =+6.07. The negative value of ΔL indicates a decrease in lightness, meaning that the emulsion appeared darker compared to the reference. The negative Δa value indicates a slight shift of the color toward the green region. Meanwhile, the positive Δb value indicates the predominance of a yellow hue in the emulsion. In this measurement, the total color difference was ΔE = 9.03, which indicates a noticeable color change in the sample.

During the second measurement, the values ΔL = +3.14, Δa = -3.65 and Δb = +2.82 were obtained. The positive ΔL value indicates an increase in the lightness of the emulsion. At the same time, the negative Δa value suggests the presence or strengthening of a greenish tone. Although the Δb value remained positive, its magnitude decreased compared to the first measurement, indicating a reduction in the yellow hue. The total color difference in this case was ΔE =5.58, which is lower than in the first measurement and indicates a reduced level of color variation.

The third measurement showed the following results: ΔL = -2.81, Δa =-1.79 and Δb =+3.77. In this case, the lightness of the emulsion slightly decreased again, although the change was not significant. The Δa parameter indicates a weak shift toward the green region, while the positive Δb value shows that the yellow hue remained present in the emulsion. The overall colour difference was ΔE = 5.03.

Overall, the obtained results demonstrate that although some variations in colour parameters were observed between measurements, the decrease in ΔE values indicates a relative stabilization of the colour characteristics. This behavior may be associated with a more uniform distribution of components within the emulsion system and formation of a more stable structure. R. Chanamai et al. studied the effect of droplet characteristics on the transmission of light through diluted monodisperse oil-water emulsions in the presence and absence of a dye [17].

The structural stability of the emulsion was evaluated using the centrifugation method. The initial mass of the emulsion sample was 2.86 g and after centrifugation 0.51 g of liquid phase was separated.

The calculated structural stability of the emulsion was 82.2%. This result indicated that the emulsion system possesses relatively good structural stability and that the dispersed phase droplets are sufficiently stabilized within the system. Wijarnprecha K. et al. studied the Structural and rheological properties of oleogels consisting of 0.5–25 wt % rice bran wax (RBX) in rice bran oil (RBO) were explored [18].

According to the literature data, the water activity of food emulsions typically ranges from 0.90 to 0.95. For example, a study published in Food Chemistry reported aw values of 0.904 for butter, 0.914 for margarine, and 0.947 for mayonnaise emulsions [19]. The water activity obtained in the present study (aw=0.947) is consistent with these literature values and indicates a relatively high level of free water within the emulsion system. The water activity of the emulsion presented in Figure 5.

Figure 5 – The water activity of the emulsion

Conclusion

The developed emulsion demonstrated satisfactory physicochemical properties. The pH value (5.64 ± 0.12) indicates a moderately acidic environment suitable for food applications and consistent system stability. The structured lipid matrix formed by rice bran wax and stabilized by chickpea proteins contributed to maintaining emulsion integrity during storage at 4°C.

Rheological analysis confirmed that the system exhibits shear-thinning (pseudoplastic) behavior, with apparent viscosity decreasing from 83.43 to 29.60 mPa·s as rotational speed increased from 5 to 20 rpm. This behavior reflects the progressive disruption of internal structural interactions under shear stress. The torque value at 20 rpm (10.5%) fell within the recommended measurement range, supporting the reliability of the obtained data.

The water activity (aw) of the developed emulsion was 0.947, indicating the presence of a relatively high level of free moisture in the system. Such values are typical for oil-in-water food emulsions and suggest that proper storage conditions, such as refrigeration and appropriate packaging, are necessary to ensure microbiological stability.

The emulsion colour parameters indicated a uniform and stable appearance of the system, which is an important quality attribute for consumer acceptance and product standardization. The presence of safflower oil and structured lipid components contributed to the formation of a visually homogeneous emulsion matrix.

In addition, the oil binding capacity (OBC) analysis demonstrated the ability of the structured lipid system to effectively retain oil within the matrix. This property is associated with the network formed by rice bran wax and the stabilizing action of chickpea proteins, which prevent oil separation and enhance structural stability.

Overall, the studied emulsion combines improved lipid composition with desirable technological performance. It demonstrates structural stability at rest, adequate acidity parameters, and favorable rheological characteristics for processing. These properties suggest its potential application as a structured fat system or partial animal fat replacer in food products.

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РАЗРАБОТКА ПОЛИКОМПОНЕНТНОЙ ЖИРОВОЙ ЭМУЛЬСИИ И ИССЛЕДОВАНИЕ ЕЕ ФИЗИКО-ХИМИЧЕСКИХ СВОИСТВ

В данной статье рассматривается разработка поликомпонентной жировой эмульсии и исследование её физико-химических свойств. Эмульсия имела умеренно кислый pH 5,64 ± 0,12, что свидетельствует о пригодности для пищевого применения и стабильной структурной целостности. Структурированная липидная матрица, сформированная из рисового воска и стабилизированная белками нута, сохраняла целостность эмульсии при хранении при 4 °C. Активность воды (aw) составила 0,947, отражая относительно высокий уровень свободной влаги, типичный для пищевых эмульсий масло-в-воде, что требует соблюдения правильных условий хранения для обеспечения микробиологической стабильности. Реологический анализ показал псевдопластическое поведение: кажущаяся вязкость уменьшалась с 83,43 до 29,60 мПа·с при увеличении скорости вращения, демонстрируя постепенное разрушение внутренних взаимодействий под действием нагрузки. Цвет и способность удерживать масло подтвердили однородность и стабильность системы. В целом, эмульсия сочетает улучшенный липидный состав с желательными технологическими свойствами и может использоваться как структурированная жировая система или частичная замена животного жира в различных пищевых продуктах. В дальнейшем планируется исследовать возможность применения данной эмульсии в качестве частичного заменителя животного жира в варёных колбасных изделиях.

Ключевые слова: *поликомпонентная эмульсия; сафлоровое масло; жир конины; воск рисовых отрубей; нутовая мука; полиненасыщенные жирные кислоты; заменитель жира.*

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ПОЛИКОМПОНЕНТТІ МАЙ ЭМУЛЬСИЯСЫН ӘЗІРЛЕУ ЖӘНЕ ОНЫҢ ФИЗИКА-ХИМИЯЛЫҚ ҚАСИЕТТЕРІН ЗЕРТТЕУ

Бұл мақалада поликомпонентті май эмульсиясын әзірлеу және оның физика-химиялық қасиеттерін зерттеу қарастырылады. Эмульсияның pH мәні 5,64 ± 0,12 болып, тағамдық қолдануға қолайлы және тұрақты құрылымдық қасиеттерін көрсетеді. Күріш балауызы мен ноқат ұнының әсерінен түзілген құрылымдық липидтік матрица 4 °C температурада сақтау кезінде эмульсия тұтастығын сақтады. Су белсенділігі (aw) 0,947 болып, май-судағы эмульсияларға тән салыстырмалы жоғары еркін ылғал деңгейін көрсетті, бұл микробиологиялық тұрақтылық үшін дұрыс сақтау жағдайларын талап етеді. Реологиялық талдау псевдопластикалық ағындық қасиет көрсететіні анықталды: тұтқырлық 83,43-тен 29,60 мПа·с дейін төмендеді, бұл ішкі құрылымдық байланыстардың кернеу әсерінен үзілуін көрсетеді. Эмульсияның түс параметрлері мен май ұстап қалу қабілеті біркелкілік пен тиімділікті растады. Жалпы, эмульсия жақсартылған липидтік құрам мен технологиялық тиімді қасиеттерді біріктіріп, әртүрлі тағам өнімдерінде құрылымдық май немесе жануар майының жартылай алмастырушысы ретінде қолдануға мүмкіндік береді. Алдағы зерттеулерде бұл эмульсияның пісірілген шұжық өнімдерінде жануар майының ішінара алмастырғышы ретінде қолданылу мүмкіндігі зерттеледі.

Түйін сөздер: *поликомпонентті эмульсия; мақсары майы; жылқы майы; күріш балауызы; ноқат ұны; полиқанықпаған май қышқылдары; май алмастырғыш.*

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INVESTIGATION THE TECHNOLOGICAL PARAMETERS OF THE FERMENTATION PROCESS OF A COMBINED DAIRY MIXTURE USING BUTTERMILK CONCENTRATE

Abstract: *The article presents the results of a study on the technological parameters of the fermentation process of a combined dairy mixture using buttermilk concentrate. The relevance of the research is determined by the growing interest in the utilization of secondary dairy resources with high nutritional and biological value, as well as by the need to develop scientifically grounded technologies to produce functional fermented dairy products. The aim of the study was to evaluate the effectiveness of various starter cultures under different fermentation temperature regimes of a combined dairy mixture. The object of the study was a dairy mixture consisting of skimmed cow's milk, goat's milk, and buttermilk. The influence of starter culture composition and fermentation temperature on physicochemical parameters, acidification dynamics, and curd structure formation was investigated. It was established that the combination of mesophilic and thermophilic lactic acid microorganisms significantly affects fermentation intensity, titratable acidity, and structural stability of the product. The results demonstrated that an optimal fermentation temperature promotes the formation of a homogeneous curd with improved physicochemical and sensory characteristics, whereas deviations from optimal conditions lead to structural defects and deterioration of product quality. The results obtained confirm the feasibility of a comprehensive selection of starter cultures and fermentation temperature regimes in the production of fermented dairy products based on combined dairy mixtures using buttermilk concentrate.*

Key words: *combined dairy mixture; buttermilk concentrate; fermentation; physicochemical properties; fermentation temperature; acidification dynamics.*